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   The BOC Group plc, Chertsey Road, Windlesham, Surrey, GU20 6HJ

   Patents ADP number *(if you know it)* — ~~884627002~~ 7975949001

   If the applicant is a corporate body, give the country/state of its incorporation — England

4. Title of the invention — VACUUM PUMP

5. Name of your agent *(if you have one)* — Andrew Steven BOOTH

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

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   Patents ADP number *(if you know it)* — 7975949001

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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11. I/We request the grant of a patent on the basis of this application.

Signature A S Booth Date 30/09/2003

12. Name and daytime telephone number of person to contact in the United Kingdom

Andrew Steven Booth
(01276) 807537

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VACUUM PUMP

This invention relates to a vacuum pump and in particular a compound vacuum pump with multiple ports suitable for differential pumping of multiple chambers.

In a differentially pumped mass spectrometer system a sample and carrier gas are introduced to a mass analyser for analysis. One such example is given in Figure 1. With reference to Figure 1, in such a system there exists a high vacuum chamber 10 immediately following first and second evacuated interface chambers 12, 14. The first interface chamber 12 may include a first ion guide for guiding ions from the ion source into the second interface chamber 14, and the second, middle chamber 14 may include a second ion guide for guiding ions from the first interface chamber into the high vacuum chamber 10. In this example, in use, the first interface chamber is at a pressure of around 1 mbar, the second interface chamber is at a pressure of around 10^{-3}mbar, and the high vacuum chamber is at a pressure of around 10^{-5}mbar.

The high vacuum chamber 10 and second interface chamber 14 can be evacuated by means of a compound vacuum pump 16. In this example, the vacuum pump has two pumping sections in the form of two sets 18, 20 of turbo-molecular stages, and a third pumping section in the form of a Holweck drag mechanism 22; an alternative form of drag mechanism, such as a Siegbahn or Gaede mechanism, could be used instead. Each set 18, 20 of turbo-molecular stages comprises a number (three shown in Figure 1, although any suitable number could be provided) of rotor 19a, 21a and stator 19b, 21b blade pairs of known angled construction. The Holweck mechanism 22 includes a number (two shown in Figure 1 although any suitable number could be provided) of rotating cylinders 23a and corresponding annular stators 23b and helical channels in a manner known per se.

In this example, a first pump inlet 24 is connected to the high vacuum chamber 10, and fluid pumped through the inlet 24 passes through both sets 18, 20 of turbo-

molecular stages in sequence and the Holweck mechanism 22 and exits the pump via outlet 30. A second pump inlet 26 is connected to the second interface chamber 14, and fluid pumped through the inlet 26 passes through set 20 of turbo-molecular stages and the Holweck mechanism 22 and exits the pump via outlet 30. In this example, the first interface chamber 12 is connected to a backing pump 32, which also pumps fluid from the outlet 30 of the compound vacuum pump 16. As fluid entering each pump inlet passes through a respective different number of stages before exiting from the pump, the pump 16 is able to provide the required vacuum levels in the chambers 10, 14.

In order to increase system performance, it is desirable to increase the mass flow rate of the sample and carrier gas from the source into the high vacuum chamber 10, whilst maintaining the desired pressure in the second interface chamber 14. For the pump illustrated in Figure 1, this could be achieved by increasing the capacity of the compound vacuum pump 16 by increasing the diameter of the rotors 21a and stators 21b of set 20. For example, in order to double the capacity of the pump 16, the area of the rotors 21a and stators 21b would be required to double in size. In addition to increasing the overall size of the pump 16, and thus the overall size of the mass spectrometer system, the pump 16 would become more difficult to drive in view of the increased mass acting on the drive shaft due to the larger rotors and stators of set 20.

It is an aim of the present invention to provide a differential pumping, multi port, compound vacuum pump, which can enable the mass flow rate in the system to be increased specifically where required without significantly increasing the size of the pump.

In a first aspect, the present invention provides a vacuum pump comprising a first pumping section, a first pump inlet through which fluid can enter the pump and pass through the first pumping section towards a pump outlet, second and third pumping sections, a second pump inlet through which fluid can enter the pump, the second and third pumping sections being arranged such that fluid entering the

pump through the second inlet is separated into a first stream passing through the second pumping section towards the pump outlet and a second stream passing through the third pumping section away from the pump outlet, and means for conveying fluid passing through the third pumping section towards the outlet.

By effectively replacing the second pumping section 20 of the known pump by two pumping sections, one on either side of the second inlet and with blade angles generally reversed, fluid entering the pump through the second inlet can be split into two streams flowing in different directions. One stream passes through the second section in the direction of the outlet, whilst the other stream passes through the third section away from the outlet (and thus against the usual flow direction) to conveying means, which conveys that stream towards the outlet. This can enable, for example, the mass flow rate at the second inlet, where required, to be effectively doubled in comparison to the pump illustrated in Figure 1 for an increase in pump size/length of only around 25-30%.

Minimising the increase in pump size/length whilst increasing the system performance where required can make the pump particular suitable for use as a compound pump for use in differentially pumping multiple chambers of a bench-top mass spectrometer system requiring a greater mass flow rate at, for example, the middle chamber to increase the flow rate into the analyser with a minimal increase in pump size.

In one arrangement, the conveying means is arranged to convey fluid passing through the third pumping section to a location intermediate the second pumping section and the outlet. Thus, fluid passing through the second pumping section can be combined with the fluid passing through the third pumping section upstream of the outlet. This can enable the fluid passing through the third pumping section against the usual flow direction to be connected to a similar vacuum point as the fluid passing through the intermediate pumping section 20 in the pump illustrated in Figure 1.

In the preferred embodiments, the second and third pumping sections are located between the first pumping section and the outlet. In such embodiments, the above-mentioned conveying means would additionally convey fluid passing through the first pumping section to a location intermediate the second pumping section and the outlet.

In a second aspect, the present invention provides a vacuum pump comprising a first pumping section, a first pump inlet through which fluid can enter the pump and pass through the first pumping section towards a pump outlet, second and third pumping sections located between the first pumping section and the outlet, a second pump inlet through which fluid can enter the pump, the second and third pumping sections being arranged such that fluid entering the pump through the second inlet is separated into two streams each flowing through a respective one of the second and third pumping sections, and means for conveying fluid passing through the first pumping section and fluid passing through one of the second and third pumping sections towards the outlet.

In an alternative arrangement of the conveying means, the conveying means comprises a first conduit for conveying fluid passing through the first pumping section to a position intermediate the second and third pumping sections, and a second conduit for conveying fluid passing through the third pumping section to a location intermediate the second pumping section and the outlet. This can also enable the fluid passing through the first pumping section to be connected to a similar vacuum point as the fluid passing through the pumping section 18 in the pump illustrated in Figure 1. Preferably, the pump comprises a baffle for directing fluid passing through the first pumping section and the third pumping section to a respective said conduit.

The pump preferably comprises at least a fourth pumping section, preferably a molecular drag stage, such as a Holweck stage, or a regenerative pumping stage, downstream from the first to third pumping sections for receiving fluid therefrom and outputting fluid towards the outlet

Preferably, each of the first to third pumping sections comprises a set of turbo-molecular stages. Preferably, each of these pumping sections comprises at least three turbo-molecular stages. The second and third pumping sections may comprise a similar number of stages, or, alternatively, the second pumping section may comprise a greater number of stages than the third pumping section, in order to overcome any conductance losses in the conduit means. The first pumping section may be of a different size/diameter than the second and third pumping sections. This can offer selective pumping performance.

The present invention also provides a vacuum pump comprising a first pump inlet, a pump outlet, a second pump inlet located between the first pump inlet and the pump outlet, a first pumping section having an inlet adjacent the second pump inlet, and a second pumping section having an inlet adjacent the second pump inlet.

The invention also provides a differentially pumped mass spectrometer system comprising two chambers and a pump as aforementioned for evacuating each of the chambers.

The present invention further provides a differentially pumped mass spectrometer system comprising a mass spectrometer having a plurality of pressure chambers; a vacuum pump attached thereto and comprising a plurality of pump inlets each for receiving fluid from a respective pressure chamber, a pump outlet and a plurality of pumping stages for differentially pumping the chambers; wherein the pumping stages are arranged such that fluid entering the pump from one of the chambers is split into a first stream flowing towards the outlet and a second stream flowing away from the outlet, and means for conveying the second stream towards the outlet.

Preferred features of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a simplified cross-section through a known multi port vacuum pump suitable for evacuating a differentially pumped, mass spectrometer system;

Figure 2 is a simplified cross-section through a first embodiment of a multi port vacuum pump suitable for evacuating the differentially pumped mass spectrometer system of Figure 1; and

Figure 3 is a simplified cross-section through a second embodiment of a multi port vacuum pump suitable for evacuating the differentially pumped mass spectrometer system of Figure 1.

With reference to Figure 2, a first embodiment of a vacuum pump 100 suitable for evacuating at the least the high vacuum chamber 10 and intermediate chamber 14 of the differentially pumped mass spectrometer system described above with reference to Figure 1 comprises a multi-component body 102 within which is mounted a shaft 104. Rotation of the shaft is effected by a motor (not shown) positioned about the shaft 104. The shaft 104 is mounted on opposite bearings (not shown).

The pump includes at least three pumping sections 106, 108, 110 and, optionally, a fourth pumping section 112. The first pumping section 106 comprises a set of turbo-molecular stages. In the embodiment shown in Figure 2, the set of turbo-molecular stages 106 comprises four rotor blades and three stator blades of known angled construction. A rotor blade is indicated at 107a and a stator blade is indicated at 107b.

The second pumping section 108 is similar to the first pumping section 106, and also comprises a set of turbo-molecular stages. In the embodiment shown in Figure 2, the set of turbo-molecular stages 108 also comprises four rotor blades and three stator blades of known angled construction. A rotor blade is indicated at 109a and a stator blade is indicated at 109b.

The third pumping section 110 is also similar to the first pumping section 106, and also comprises a set of turbo-molecular stages. In the embodiment shown in Figure 2, the set of turbo-molecular stages 110 also comprises four rotor blades and three stator blades of known angled construction. A rotor blade is indicated at 111a and a stator blade is indicated at 111b.

Optionally, as shown in Figure 2, downstream of the first to third pumping sections is a fourth pumping section 112 in the form of a Holweck or other type of drag mechanism. In this embodiment, the Holweck mechanism comprises two rotating cylinders 113a, 113b and corresponding annular stators 114a, 114b having helical channels formed therein in a manner known per se. Downstream of the Holweck mechanism 112 is a pump outlet 116.

As illustrated in Figure 2, the pump 100 has two inlets; although only two inlets are used in this embodiment, the pump may have three or more inlets, which can be selectively opened and closed and can, for example, make the use of internal baffles to guide different flow streams to particular portions of a mechanism. The first, low fluid pressure inlet 120 is located upstream of all of the pumping sections. The second, high fluid pressure inlet 122 is located interstage the second pumping section 108 and the third pumping section 110. A conduit 126 has an inlet 128 located interstage the first pumping section 106 and the third pumping section 110, and an outlet 130 located interstage the second pumping section 108 and the Holweck stage 112.

In use, each inlet is connected to a respective chamber of the differentially pumped mass spectrometer system. Fluid passing through the first inlet 120 from the low pressure chamber 10 passes through the pumping section 106, enters the conduit 126 at conduit inlet 128, passes out of the conduit 126 via conduit outlet 130, passes through the Holweck stage 112 and exits the pump 100 via pump outlet 116. Fluid passing through the second inlet 122 from the middle pressure chamber 14 enters the pump 100 and "splits" into two streams. One stream

passes through the second pumping section 108 and Holweck stage 112 and exits the pump via the pump outlet 116. The other stream passes through the third pumping section 110 and enters the conduit 126 at conduit inlet 128 to combine with the fluid passed through the first pumping section 106. This enables the fluid passing through the third pumping section 110 against the "usual" flow direction (i.e. away from the outlet) to be connected to a similar vacuum point as the fluid passing through the intermediate pumping section 20 in the pump illustrated in Figure 1. Fluid passing through a third inlet 124 from the high pressure chamber 12 may be pumped by a backing pump 150 which also backs the pump 100 via outlet 116.

A particular advantage of the embodiment described above is that, by providing two pumping sections (namely the second and third pumping sections 108, 110) on either side of the inlet to the middle chamber 14 of the differentially pumped mass spectrometer system, the mass flow rate of fluid entering the pump from the middle chamber 14 can be at least doubled in comparison to the known arrangement shown in Figure 1, without varying the level of the vacuum in the middle chamber. Thus, the flow rate of sample and carrier gas entering the high vacuum chamber 10 from the middle chamber can also be increased, increasing the performance of the differentially pumped mass spectrometer system.

With reference to Figure 3, a second embodiment of a vacuum pump 200 suitable for evacuating the high vacuum chamber 10 and intermediate chamber 14 of the differentially pumped mass spectrometer system is similar to the first embodiment, save that the conduit 126 is replaced by a first conduit 202 and a second conduit 208. The first conduit 202 has an inlet 204 located interstage the first pumping section 106 and the third pumping section 110, and an outlet 206 located interstage the second pumping section 108 and the third pumping section 110. The second conduit 208 has an inlet 210 located interstage the first pumping section 106 and the third pumping section 110, and an outlet 212 located interstage the second pumping section 108 and the Holweck stage 112. A baffle member 220 ensures that fluid passing through the first pumping section 106

enters the first conduit 202 and the fluid passing through the third pumping section 110 enters the second conduit 208. This arrangement can enable both the fluid passing through the third pumping section against the usual flow direction to be connected to a similar vacuum point as the fluid passing through the intermediate pumping section 20 in the pump illustrated in Figure 1, and the fluid passing through the first pumping section to be connected to a similar vacuum point as the fluid passing through the pumping section 18 in the Figure 1 pump.

CLAIMS

1. A vacuum pump comprising a first pumping section, a first pump inlet through which fluid can enter the pump and pass through the first pumping section towards a pump outlet, second and third pumping sections, a second pump inlet through which fluid can enter the pump, the second and third pumping sections being arranged such that fluid entering the pump through the second inlet is separated into a first stream passing through the second pumping section towards the pump outlet and a second stream passing through the third pumping section away from the pump outlet, and means for conveying fluid passing through the third pumping section towards the outlet.

2. A pump according to Claim 1, wherein the conveying means is arranged to convey fluid passing through the third pumping section to a location intermediate the second pumping section and the outlet.

3. A pump according to Claim 1 or 2, wherein the second and third pumping sections are located between the first pumping section and the outlet.

4. A pump according to Claim 3 when dependent from Claim 1, wherein the conveying means comprises a first conduit for conveying fluid passing through the first pumping section to a position intermediate the second and third pumping sections, and a second conduit for conveying fluid passing through the third pumping section to a location intermediate the second pumping section and the outlet.

5. A pump according to Claim 4, comprising a baffle for directing fluid passing through the first pumping section and the third pumping section to a respective said conduit.

6. A pump according to any preceding claim, comprising at least one additional pumping section downstream from the first, second and third pumping sections for receiving fluid therefrom and outputting fluid towards the outlet.

7. A pump according to Claim 6, wherein said at least one additional pumping section comprises a molecular drag stage or a regenerative pumping stage.

8. A pump according to any preceding claim, wherein each of the first, second and third pumping sections comprises at least one turbo-molecular stage.

9. A pump according to Claim 8, wherein each of the first, second and third pumping sections comprises at least three turbo-molecular stages.

10. A vacuum pump comprising a first pumping section, a first pump inlet through which fluid can enter the pump and pass through the first pumping section towards a pump outlet, second and third pumping sections located between the first pumping section and the outlet, a second pump inlet through which fluid can enter the pump, the second and third pumping sections being arranged such that fluid entering the pump through the second inlet is separated into two streams each flowing through a respective one of the second and third pumping sections, and means for conveying fluid passing through the first pumping section and fluid passing through one of the second and third pumping sections towards the outlet.

11. A vacuum pump comprising a first pump inlet, a pump outlet, a second pump inlet located between the first pump inlet and the pump

outlet, a first pumping section having an inlet adjacent the second pump inlet, and a second pumping section having an inlet adjacent the second pump inlet.

12. A vacuum pump substantially as herein described with reference to any of Figures 2 and 3 of the accompanying drawings.

13. A differentially pumped mass spectrometer system comprising two chambers and a pump according to any preceding claim for evacuating each of the chambers.

14. A differentially pumped mass spectrometer system comprising a mass spectrometer having a plurality of pressure chambers; a vacuum pump attached thereto and comprising a plurality of pump inlets each for receiving fluid from a respective pressure chamber, a pump outlet and a plurality of pumping stages for differentially pumping the chambers; wherein the pumping stages are arranged such that fluid entering the pump from one of the chambers is split into a first stream flowing towards the outlet and a second stream flowing away from the outlet, and means for conveying the second stream towards the outlet.

15. A differentially pumped mass spectrometer system substantially as herein described with reference to any of Figures 2 and 3 of the accompanying drawings.

ABSTRACT

A vacuum pump 100 comprises a first set 106 of turbo-molecular stages, a molecular drag stage 112, a first inlet 120 through which fluid can pass through the first set 106 of stages and the molecular drag stage 112 towards a pump outlet 116, second and third sets 108, 110 of turbo-molecular stages located between the first set 106 and the molecular drag stage 112, a second inlet 122, the second and third sets 108, 110 being arranged such that fluid entering the pump through the second inlet 122 is separated into two streams each flowing through a respective one of the second and third sets 108, 110, and conduit means 126 for conveying fluid passing through the first set 106 and one of the second and third sets 108, 110 towards the outlet 116.

(Figure 2)

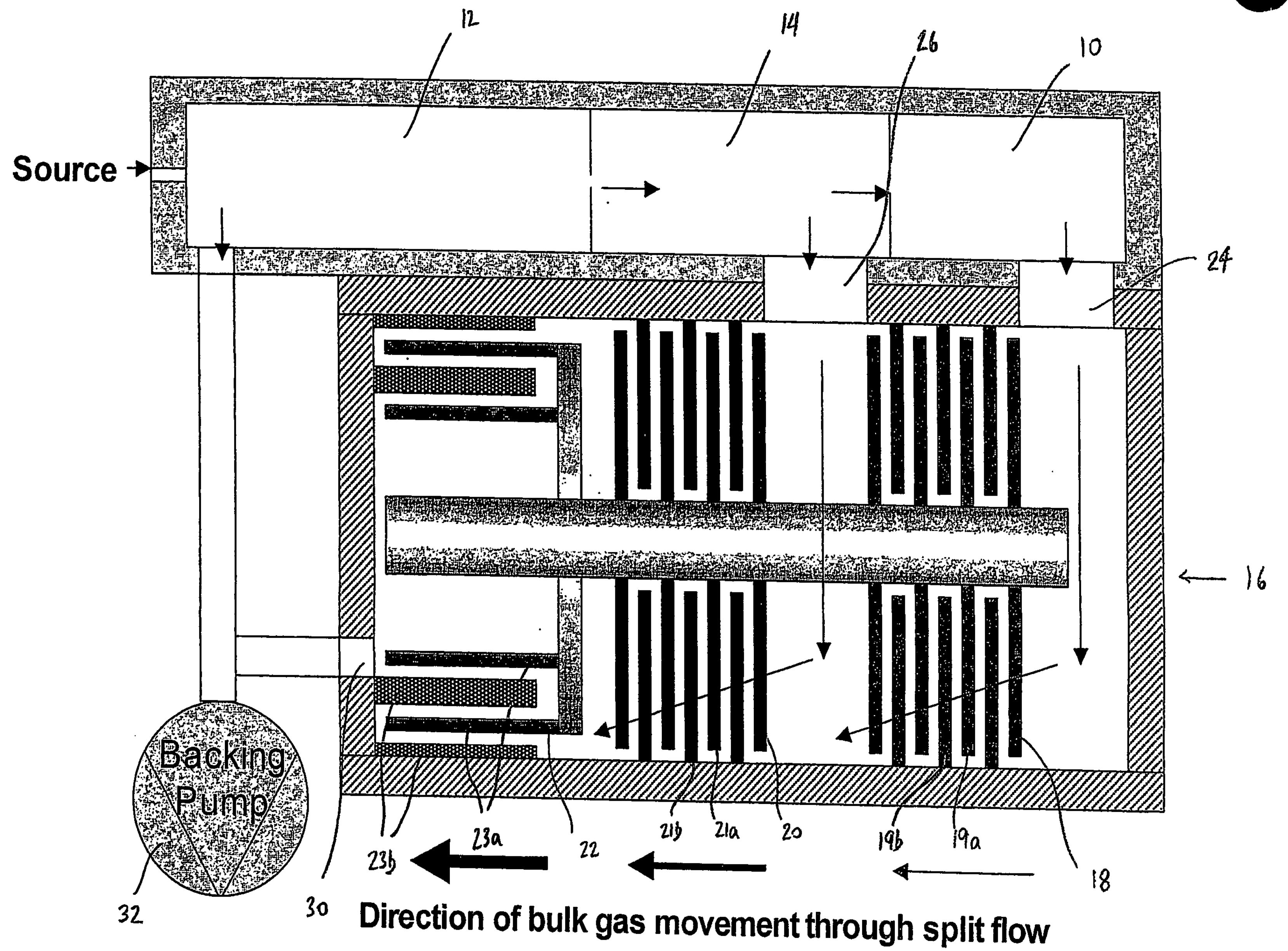
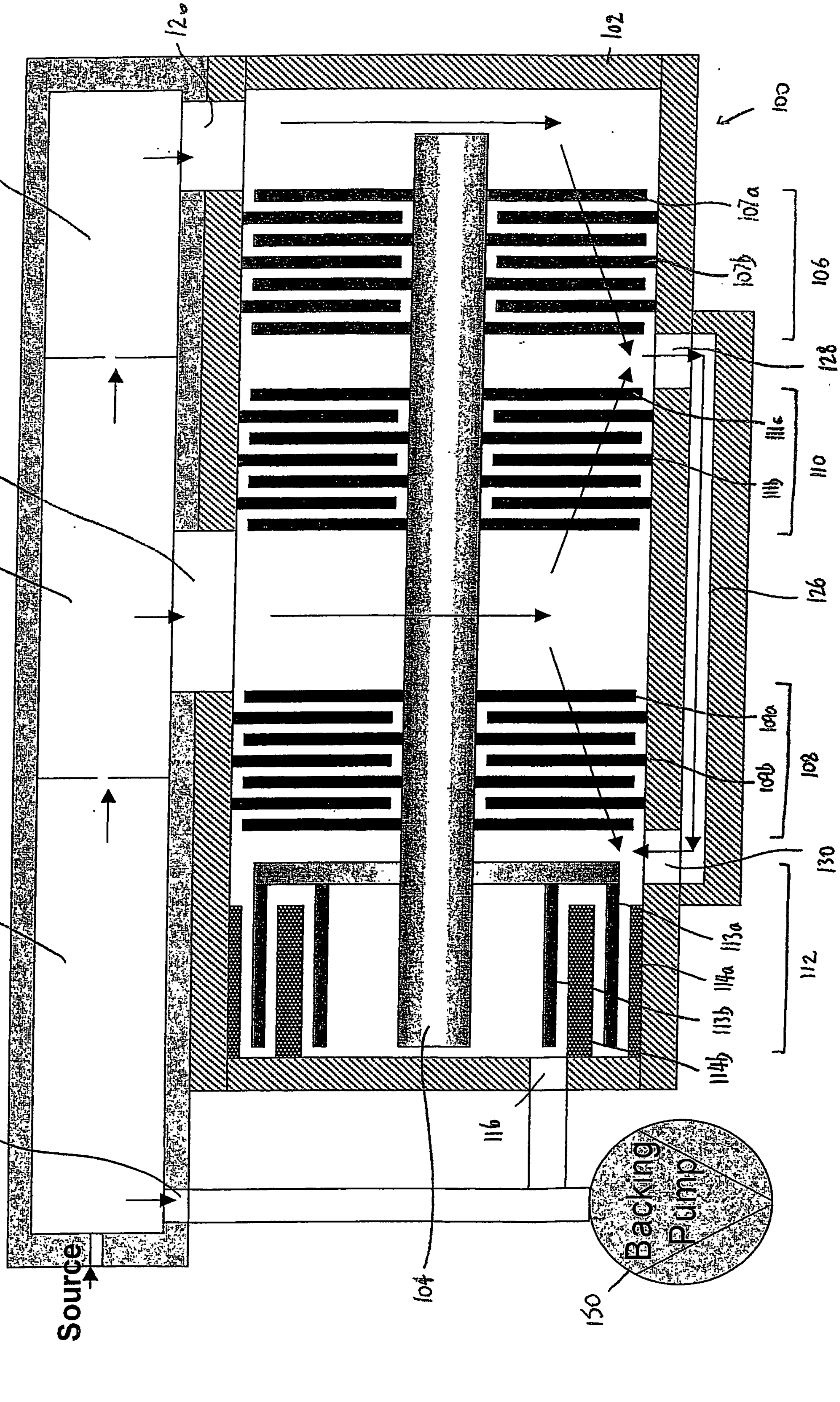


FIG. 1 (PRIOR ART)



10
12
14
120
122
124
102
100
104
106
107a
107b
108
109a
109b
110
111a
111b
112
113a
113b
114a
114b
116
126
128
130
150
Source
Backing Pump

FIG 2

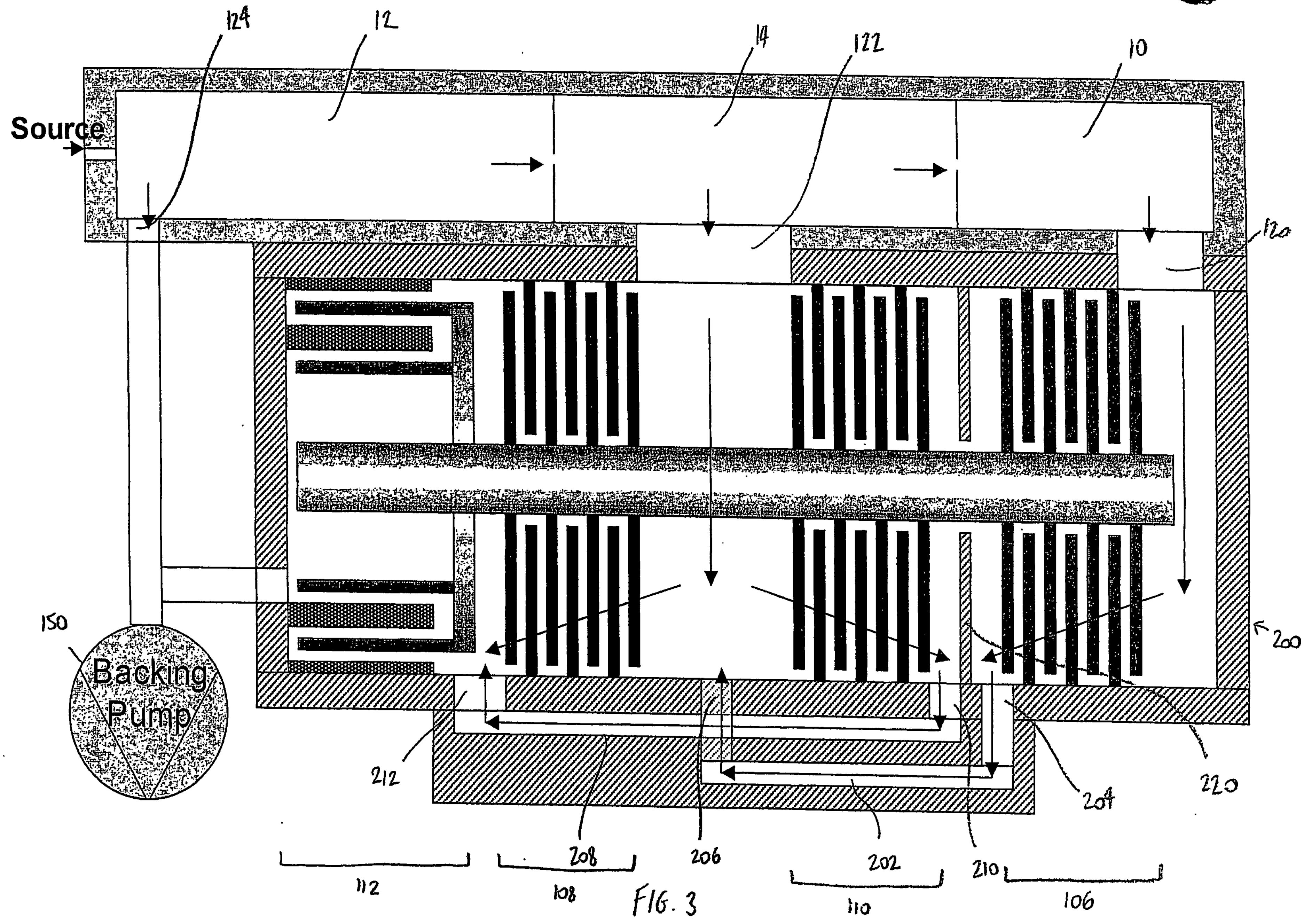

Source
Backing Pump
124
12
14
122
10
120
150
200
212
208
206
202
210
204
220
112
108
110
106

FIG. 3

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